The Planetary CubeSats Symposium, August 16th, 2018

Imaging Systems for CubeSats

Matt Clark
Project Manager

Malin Space Science Systems, Inc.

Agenda

- Introduction of Malin Space Science Systems
- Overview of the ECAM Space Camera Platform
- Recent CubeSat proposals and studies

Malin Space Science Systems

- Who we are
  - Headquartered in San Diego
  - 27 years in the space business
  - 73 employees
- What we do
  - Imaging system development
  - Mission operations
  - Science data analysis
  - Micro Missions Systems
- Track record
  - Cumulative 100+ instrument years of deep space operations
  - Currently operating
    - Three cameras orbiting the Moon
    - Three cameras orbiting Mars
    - Four cameras on the surface of Mars
    - One camera orbiting Jupiter
  - NASA JPL Small Business Prime Subcontractor of the Year Award for 2015
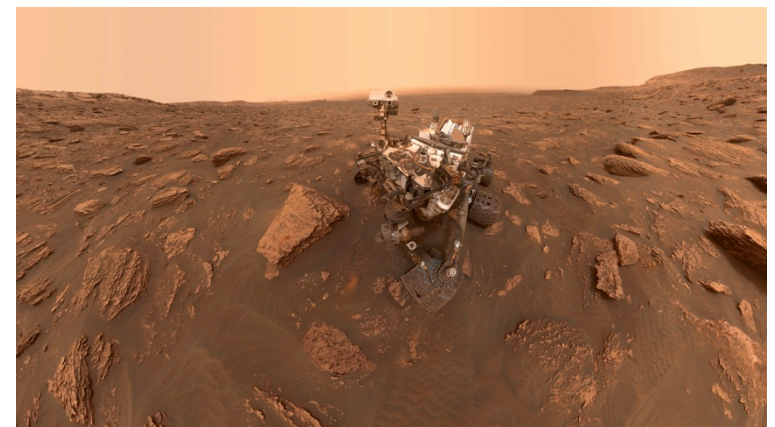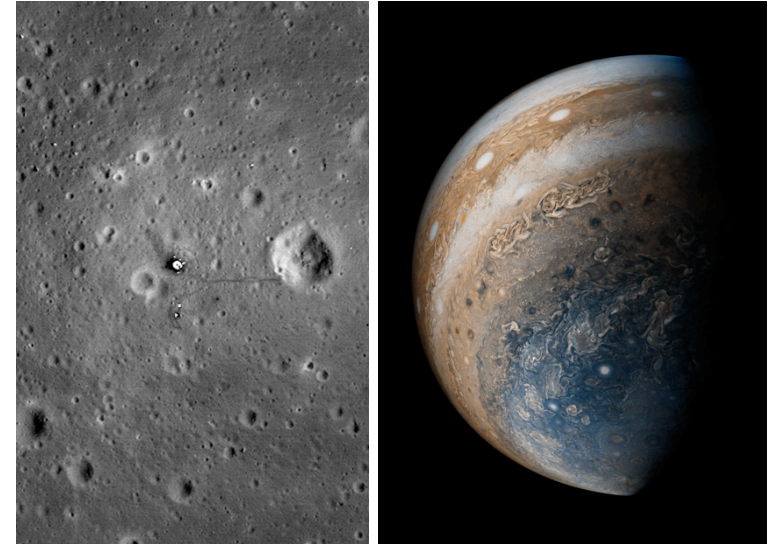
MSSS Flight Experience

- 39 flight instruments
- 21 missions (Mars, Jupiter, Earth, Earth's Moon, asteroid Bennu)

- 1,000,000+ images commanded & downlinked
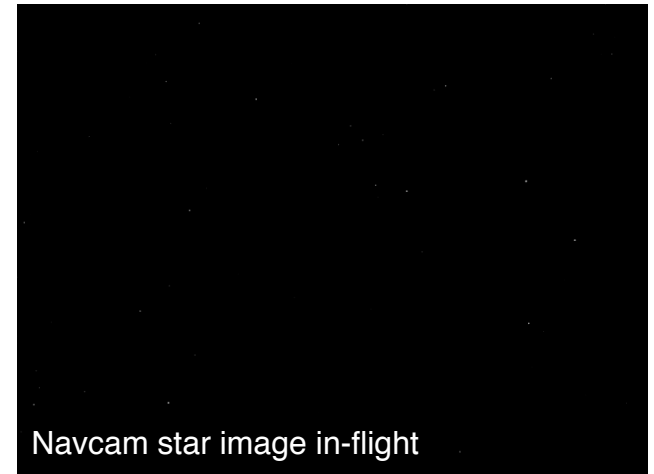- 760,000+ operational hours

Our Customers

- NASA Goddard Space Flight Center (LRO, Restore-L)
- NASA Jet Propulsion Laboratory (MSL, Mars 2020, Juno, etc…)
- Arizona State University (Mars2020, Psyche, Shadowcam)
- Lockheed Martin (OSIRIS-REX, Lucy)
- Naval Research Laboratory (RSGS)
- ITT Exelis (GOSAT)
- Northrop Grumman Innovation Systems (Classified programs)
- Boeing (Classified programs)

Engineering Camera (ECAM)

- Developed under MSSS IRAD, ECAM is a modular space camera platform built to strict NASA standards.

- While it was originally targeted towards engineering applications, ECAM systems have been used for:
  - In-flight diagnostics
  - Deployment/actuator monitoring
  - Space situational awareness
  - Science observations
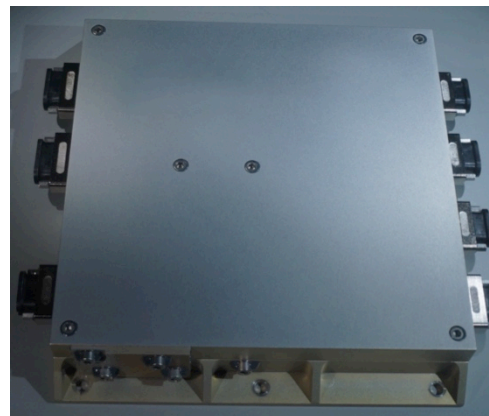 - Public outreach
  - Optical navigation

Navcam star image in-flight
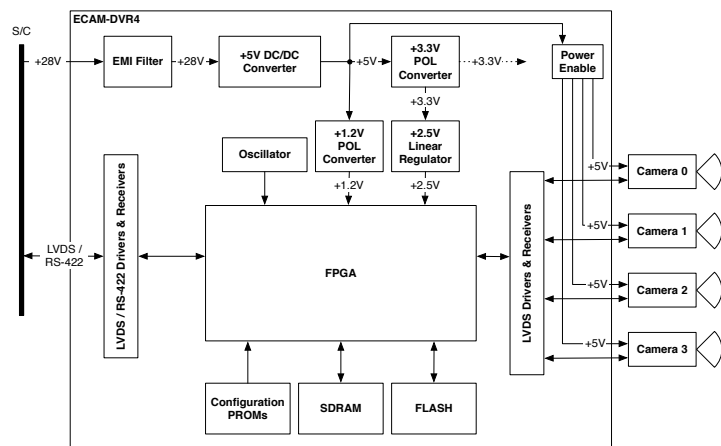
ECAM flight unit for OSIRIS-REx
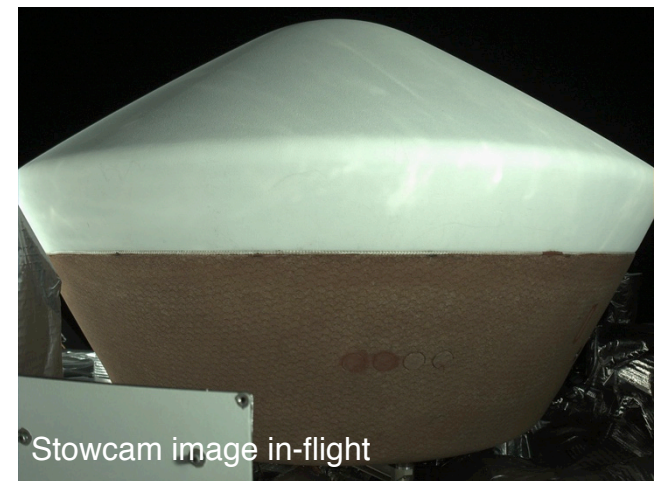
Stowcam image in-flight

6

ECAM Architecture—DVR

- DVR interfaces to cameras (power, data, commanding).

- DVR processes and stores data (Bayer pattern interpolation, compression, and buffering—from 8 to 32 Gbytes of flash).

- DVR provides one power (28 V) and one data interface to the S/C.

- DVR baseline I/F is SpaceWire, but it can accommodate any customer specified four-line LVDS or RS-422 interface.

- DVRs can be daisy-chained, making a DVR8 or DVR12, still with a single S/C command/data interface.

ECAM Architecture—Camera Heads

ECAM-C50	ECAM-P50	ECAM-IR3a

- 5MP CMOS sensor (color or B/W)
- 2.2μm pixel pitch
- (2592 x 1944)
- Rolling Shutter
- Commandable exposure

- 5MP CMOS sensor (color or B/W)
- 4.8μm pixel pitch
- (2592 x 2048)
- Global Shutter
- Commandable or Auto exposure

- VGA format uncooled microbolometer
- 17μm pixel pitch (640 x 480)
- Optional calibration flag

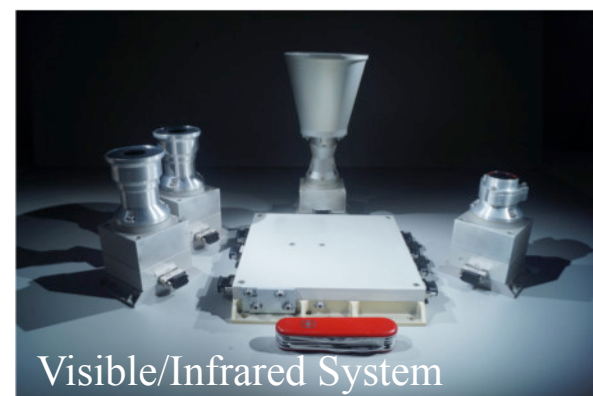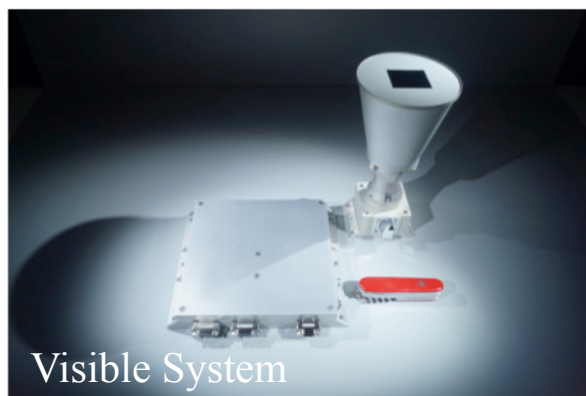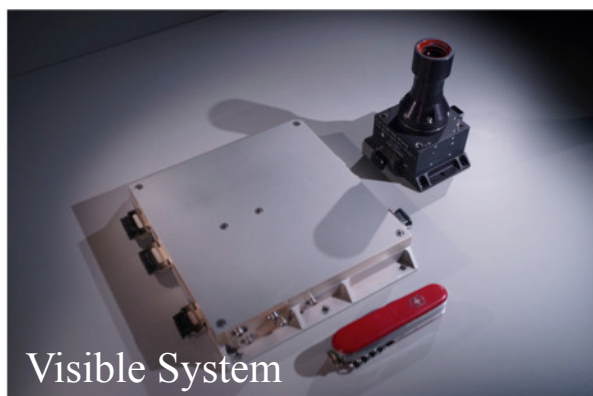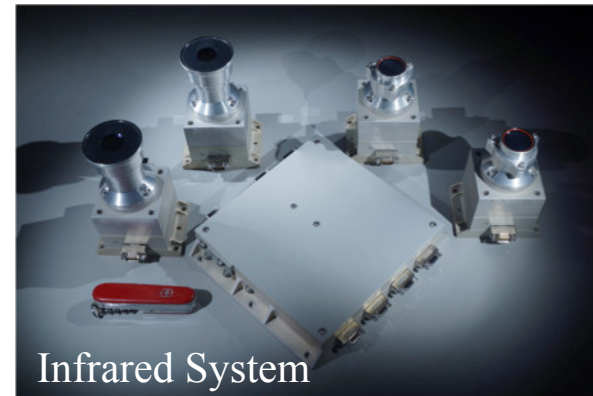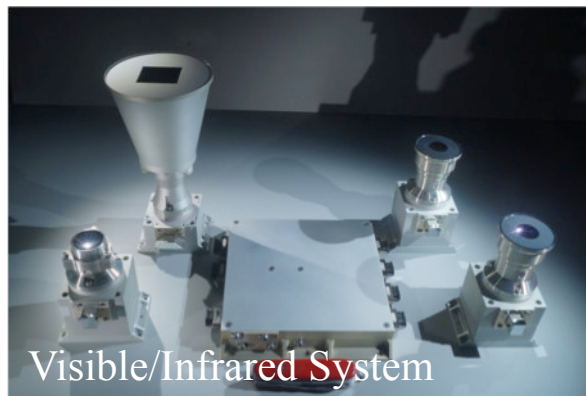*Variety of standard optics available without NRE

Quality and Heritage

- ECAM system components meet the requirements of NASA EEE-INST-002, Level 2.
  - The parts list was approved by the GSFC Parts Control Board for the OSIRIS-REX program.
- ECAM hardware can be customized for different environments. Systems have been delivered for:
  - Deep space
  - Low Earth Orbit
  - Geosynchronous Orbit
- All standard ECAM subsystems have a NASA Test Readiness Level of 9.

ECAM Systems Delivered to Date

Visible System

Visible/Infrared System

Infrared System

Visible System

Visible System

Visible/Infrared System

Recent CubeSat Imaging System Case Studies

- MSSS has recently proposed ECAM systems for several CubeSat SIMPLEx proposals:
  - Mars Micro Orbiter (MMO), Malin Space Science Systems
  - PrOVE, UM/NASA GSFC
- These illustrate that there are options for imaging systems that fit on CubeSats that also have heritage, reliability and performance.

Mars Micro Orbiter (MMO)

- PI: Mike Malin, MSSS

- Instrument Purpose:
  - To conduct global observations of Mars from orbit in visible and infrared wave-lengths to monitor its atmosphere.

- The payload consists of:
  - One visible camera
 - Two thermal IR cameras with a shared filter wheel
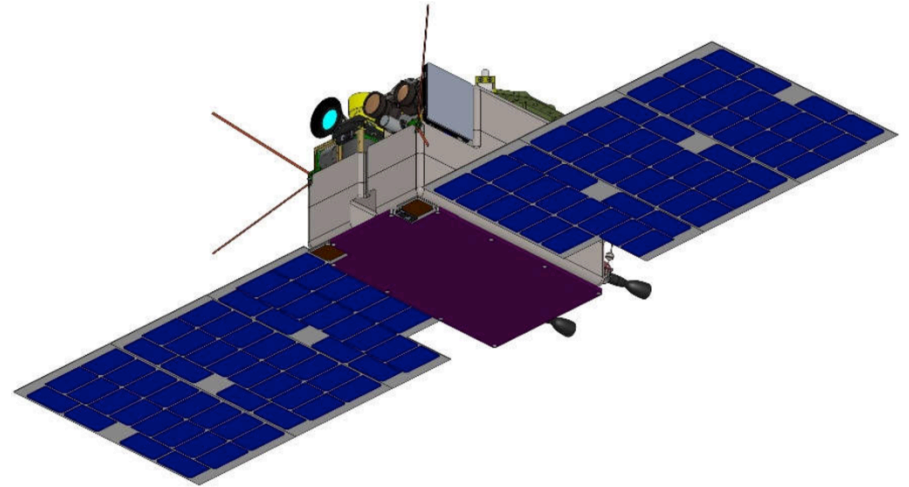
MMO Visible Camera—Description

- ECAM-C50 visible camera w/WFOV lens

  - 5MP CMOS sensor, 2.2μm pixel pitch (2592 x 1944)

  - Bayer Pattern Filter for RGB color

  - WFOV lens (55° x 76°)

  - FPGA-based architecture

  - 5V power, 100 Mbps SpaceWire interface

  - Mass: 400g

  - 57mm x 78mm x 108mm
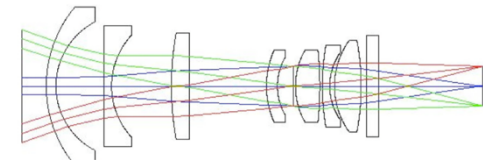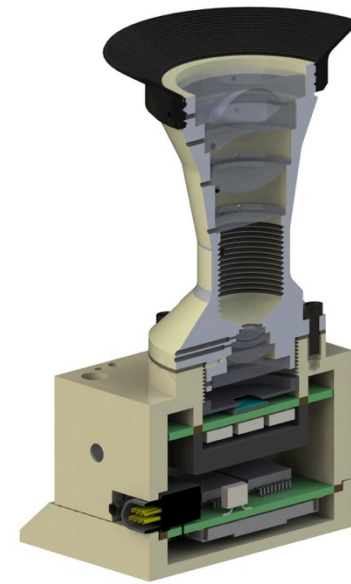
MMO Thermal IR Cameras—Description

- Two ECAM-IR3a thermal infrared camera w/Mars2020 Mastcam filter wheel

  - VGA format with 17μm pixel pitch (640 x 480) Uncooled Microbolometer

  - 2 MFOV lenses (20° x 27°)

  - FPGA-based architecture

  - 5V power, 100Mbps SpaceWire interface

 - Mass: ~1400g

  - 91mm x 130mm x 108mm
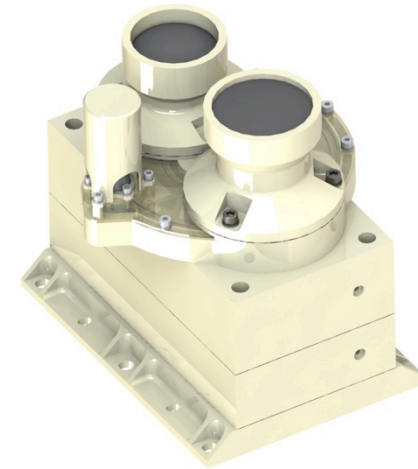
MMO IR Optics

- The IR system integrates two cameras with a shared eight position filter wheel

  - Each camera can image through three bandpass filters.

  - Each camera has a calibration target as its fourth "filter".

  - Heritage filter wheel driven by Cobham stepper motor.

  - One lens is optimized for 7.5 μm to 13 μm, the other for 14 μm to 16.5 μm.

  - The ability to adjust focus with filter thickness relaxes the axial chromatic correction.
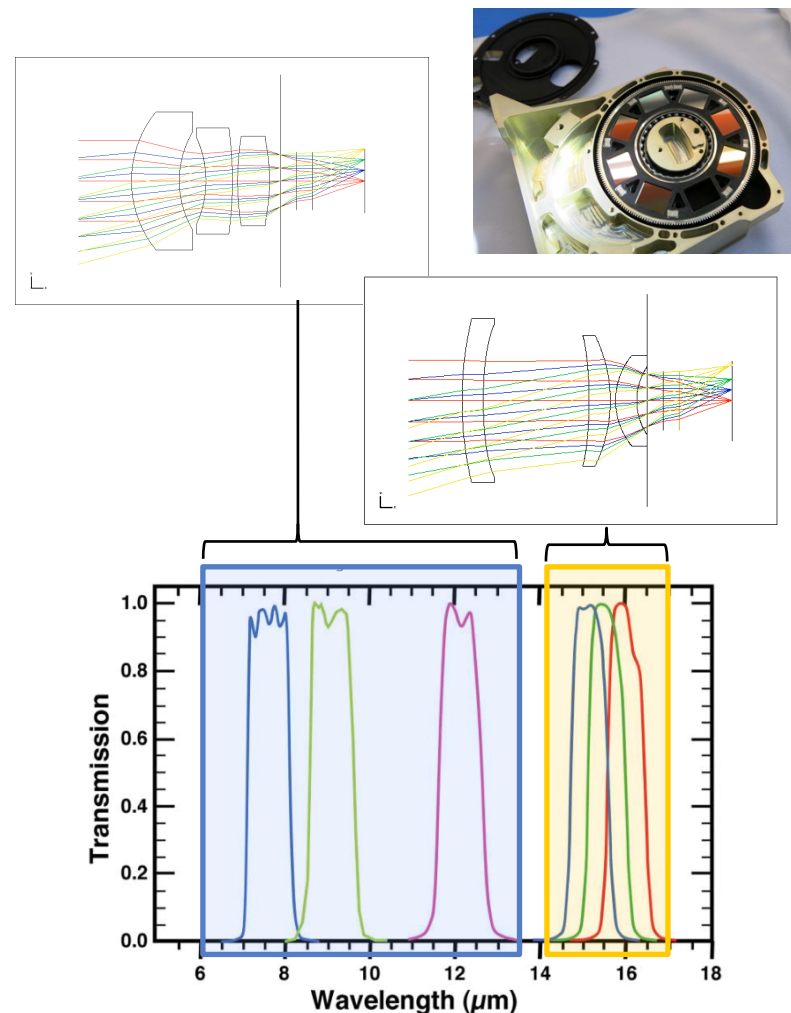
Primitive Object Volatile Explorer (PrOVE)

- PI: Tilak Hewagama, UM
- MSSS's contribution is VisCAM:
  - An ECAM-M50 with custom optics that provides 8m spatial resolution at 300km.
  - ECAM-DVR4 provides power conditioning, camera control, image processing, compression, and storage.
- Instrument Purpose:
  - Provide high spatial resolution mapping of a Jupiter-family comet surface and/or a new comet surface.
  - These maps will provide the first observations of a new comet surface.

16
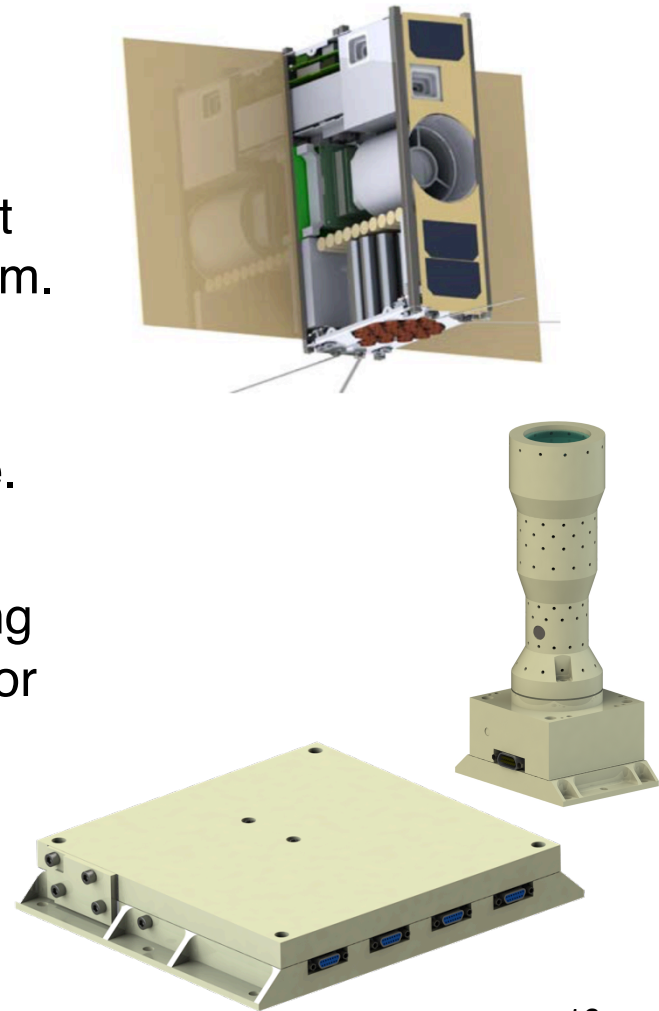
VisCAM Instrument—Description

- ECAM-M50 visible camera w/ custom optics

  - 5MP Monochrome CMOS sensor, 2.2μm pixel pitch (2592 x 1944)

  - Custom 132mm, F/4.2 lens (1.9° x 2.5°)

  - FPGA-based architecture

  - 5V power, 100Mbps SpaceWire interface

  - Mass: 600 g

  - 57mm x 78mm x 164mm

Conclusion

- The MSSS ECAM architecture provides viable options for CubeSat applications where high reliability, heritage, and performance are required.

- ECAM system components are built to NASA reliability standards and are now flying on multiple missions (TRL 9).

- ECAM systems can be customized for a range of environments, applications, and configurations.

- This shows that imaging systems with science-driven performance that meet NASA deep space requirements can be compatible with CubeSat missions.